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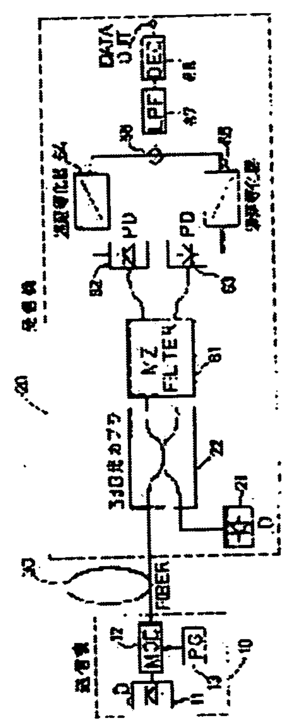
(54) RECEIVER AND TRANSMITTER-RECEIVER FOR COHERENT OPTICAL COMMUNICATION



(57)Abstract:
PURPOSE: To remove an up-convert after a base band detection, and to compensate the distribution of an optical fiber only by a base band processing by dividing signal components having a relative delay time of a mutual reversed polarity, overlapped on the base band in an optical area, in the base band detection such as an optical homodyne detection.
CONSTITUTION: A received signal received from a transmitter 10 through an optical fiber transmission path 30, and a local oscillation light from a semiconductor laser light source 21 are inputted to a coupler 22 of a receiver 20, synthesized, and inputted to a Mach Zender type optical filter 61 with a ring oscillator, and this signal spectrum is divided into upper and lower side wave bands. Next, the spectrum divided into the upper side band is coherent-detected by a photodetector 62 by using a local oscillation light, and the spectrum divided into the lower side band is detected in the same way by a photodetector 63. Then, the distribution of the base band signal detected by the photodetector 62 generated at an optical fiber is compensated by using a delay equalizer 64, and the distribution of the signal detected by the photodetector 63 at the optical fiber is also compensated by using a delay equalizer 65.

LEGAL STATUS

JP H616-53906

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the receiver for coherent optical communication, and a transmitter-receiver, and relates to the receiver for coherent optical communication and transmitter-receiver which enable distributed compensation of an optical fiber in an electric field in baseband detection of optical homodyne detection etc. especially.
[0002]
[Description of the Prior Art] It divides roughly into the detection method of coherent optical communication, and there are a heterodyne detection method and homodyne detection in it.
[0003] To the demand band of a photodetector being 2 to 3 times the bit rate, with homodyne detection, since the demand band of a photodetector is bit rate extent, it is suitable for improvement in the speed with the heterodyne detection method.
[0004] Drawing 9 shows the block diagram of the conventional heterodyne detection method. As for the configuration of the transmitter-receiver shown in this drawing, the transmitter 10 and the receiver 20 are connected on the optical-fiber-transmission way 30. A transmitter 10 consists of semiconductor laser 11, a modulator 12, and a pulse pattern generator 13, and a receiver 20 is constituted by 21 or 3dB light coupler 22 of semiconductor laser, a photodetector 23, a delay equalizer 24, and the demodulator circuit 25. In the configuration of this drawing, a transmitter 10 generates carrier light by semiconductor laser 11, modulates carrier light with a modulator 12 according to the pulse pattern generator 13, and sends it out to a receiver 20 through the optical-fiber-transmission way 30.
[0005] It multiplexs, the receiving light which received through the optical-fiber-transmission way 30 using the optical coupler 22, and the local oscillation light generated by the semiconductor laser light source 21 are detected with a photodetector 23, and a receiver 20 inputs it into a delay equalizer 24. A delay equalizer 24 inputs the equalized intermediate frequency band signal into a demodulator 25. A demodulator 25 outputs the baseband signaling to which it restored.
[0006] Drawing 10 shows the signal spectrum and relative time delay before and behind heterodyne detection. Among this drawing, (a) shows a heterodyne detection front and (b) shows the heterodyne detection back. Since the signal spectrum of an optical field is changed into an intermediate frequency (IF) band as it is, heterodyne detection can compensate distribution of an optical fiber in an electric field by inserting the delay equalizers 24, such as a microstrip line, (KIwashita N.Takachio, IEEE J.Lightwave Technol., vol No 3, pp 367-375 1990).
[0007] Drawing 11 shows the block diagram of the conventional homodyne detection. The same sign is shown in the same component as drawing 9 in the said drawing, and the explanation is omitted. The baseband signaling which multiplexed local oscillation light and receiving light with the optical coupler 22, and was detected with the photodetector 23 is outputted through a low pass filter 41 and the distinction machine 42.
[0008] Drawing 12 shows the signal spectrum and relative time delay in homodyne detection. This drawing (a) shows the optical frequency band before homodyne detection, and this drawing (b) shows the baseband after homodyne detection. By drawing 11 and drawing 12 , with homodyne detection, the upper sideband and lower sideband of a signal

spectrum will be in the condition of having been folded up by baseband, and the component which had the relative time delay of a reverse property mutually will lap with the same frequency band (baseband). Therefore, unlike a heterodyne method, distribution of an optical fiber cannot be compensated in an electric field with a delay equalizer.

[0009] "Duplex phase diversity method" (Ogoe and Yamashita, Shingaku Giho, CS88-78/IE 88-82, PP.7-14, 1988.) which, on the other hand, enables distributed compensation by the delay equalizer in the phase diversity detection method which is one of the detection methods of baseband that this problem should be solved It is proposed.

[0010] Drawing 13 shows the block diagram of a duplex phase diver city method. In this drawing, the same sign is given to the same part as drawing 9 , and the explanation is omitted.

[0011] The input signal which received the receiver 20 of this drawing through the optical-fiber-transmission way 30, and the signal which the partial oscillation light by which it was generated by the semiconductor laser light source 21 was inputted into the optical hybrid 51, was divided into the I signal and the Q signal, and was separated are inputted into photodetectors 52 and 53, respectively. The multiplication of what shifted the phase of the output of photodetectors 52 and 53 and the output of a voltage controlled oscillator 55 pi/2 is carried out with multipliers 56 and 57, and each output by which multiplication was carried out is added with an adder 58, and it is a delay equalizer 24, equalizes, and gets over and outputs with a demodulator 25. This method is a method which separates the vertical sideband component folded up by baseband signaling on a frequency shaft, and enables distributed compensation of the optical fiber by the delay equalizer 24 by carrying out rise KOMBADO of the baseband signaling which carried out phase diversity detection once at an intermediate frequency (IF) band.

[0012]

[Problem(s) to be Solved by the Invention] However, although the above-mentioned conventional heterodyne detection method has the advantage that distribution of an optical fiber can be compensated with an intermediate frequency (IF) band, it has the fault that the demand band of a photodetector is very as high as two to 3 times of a bit rate. On the other hand, although the demand band of a photodetector is good at bit rate extent, distributed compensation of an optical fiber cannot do homodyne detection in an electric field.

[0013] Moreover, the demand band of a photodetector is bit rate extent, and its distributed compensation of an optical fiber is possible for a duplex phase diversity method with an intermediate frequency (IF) band. However, in order to carry out the rise convert of the detected baseband signaling to an intermediate frequency (IF) band once, broadband IF band demodulator circuit is needed.

[0014] This invention was made in view of the above-mentioned point, and it aims at offering the receiver for coherent optical communication and transmitter-receiver which enable distributed compensation of an optical fiber by baseband processing altogether in order to aim at improvement in transmission speed.

[0015]

[Means for Solving the Problem] The light source for local oscillation to which this invention carries out outgoing radiation of the local oscillation light in coherent optical communication, The optical coupling machine which multiplexs input-signal light and local oscillation light, and the optical filter for dividing a signal spectrum into a vertical

sideband, Two photodetectors which detect the signal spectrum divided into two with the optical filter, respectively, and acquire two baseband signaling, It has the relative time delay of a reverse property mutually, and two delay equalizers which equalize two baseband signaling acquired by the photodetector, and the adder which adds and outputs two baseband signaling by which identification was carried out with the delay equalizer are included.

[0016] Moreover, this invention detects one of the light source for local oscillation which carries out outgoing radiation of the local oscillation light, the optical coupling machine which multiplexs input-signal light and local oscillation light, the optical filter for dividing a signal spectrum into a vertical sideband, and the signal spectrums divided into two in coherent optical communication, and contains the delay equalizer for equalizing the baseband signaling acquired with the photodetector which acquires baseband signaling, and the photodetector, and outputting the baseband signaling by which identification was carried out.

[0017] The coherent light communications transmitter which transmits only the piece sideband with which this invention was filtered by the optical filter including the optical filter for dividing into a vertical sideband the signal spectrum modulated by the modulator in coherent optical communication, The light source for local oscillation, and the optical coupling machine which multiplexs local oscillation light in input-signal light, The signal it was multiplexed [signal] with the optical coupling vessel is detected, and it is constituted by the receiver for coherent optical communication containing the photodetector which acquires baseband signaling, and the delay equalizer for equalizing the baseband signaling detected with the photodetector.

[0018]

[Function] This invention separates spatially the signal spectrum component which laps with the same frequency band (baseband) in baseband detection of optical homodyne detection etc. with the optical filter which divides a signal spectrum into a vertical sideband in a receiving side and which has the relative time delay of a reverse property mutually. Coherent detection of the two separated signal spectrums is carried out with a photodetector using local oscillation light. Distribution of an optical fiber can be compensated by inserting two detected baseband signaling in two baseband equalizers which had the relative time delay of a reverse property mutually.

[0019] Moreover, in baseband detection of optical homodyne detection etc., the signal spectrum component which laps with the same frequency band (baseband) and which has the relative time delay of a reverse property mutually is spatially separated by dividing a signal spectrum into a vertical sideband using this optical filter by the receiving side. Distribution of an optical fiber is compensated by carrying out coherent detection of one of the separated signal spectrums with a photodetector using local oscillation light, and inserting the detected baseband signaling in a baseband equalizer.

[0020] As mentioned above, in baseband detection of optical homodyne detection etc., it is avoided by dividing input-signal light into a vertical sideband with an optical filter that the signal spectrum component which has the relative time delay of a reverse property mutually laps with the same frequency band (baseband). Therefore, distributed compensation of an optical fiber is attained by inserting a delay equalizer after detection.

[0021] Furthermore, in baseband detection of optical homodyne detection etc., the signal spectrum component which laps with the same frequency band (baseband) and which has

the relative time delay of a reverse property mutually is spatially separated by dividing a signal spectrum into a vertical sideband using an optical filter by the transmitting side. It transmits to a receiver by making one of the separated signal spectrums into a sending signal. Coherent detection is carried out with a photodetector using local oscillation light, and distribution of an optical fiber is compensated with a receiving side by inserting the detected baseband signaling in a baseband equalizer. When baseband detection of optical homodyne detection etc. is performed by the receiving side by generating a piece sideband (SSB:SingleSide Band) signal and transmitting the signal to a receiving side, when this divides into a vertical sideband the signal light modulated by the transmitting side with an optical filter, it is avoided that the signal spectrum component which has the relative time delay of a reverse property mutually laps with the same frequency band (baseband). Therefore, distributed compensation of an optical fiber is attained by inserting a delay equalizer after detection.

[0022]

[Example] Drawing 1 shows the block diagram of the 1st example of this invention. The same sign is given to the same component as drawing 9 among this drawing, and the explanation is omitted.

[0023] From the semiconductor laser light source 21, the local oscillation light by which outgoing radiation was carried out is inputted, and the coupler 22 of a receiver 20 multiplexs with the input signal which received through the optical-fiber-transmission way 30 from the transmitter 10, and is inputted into the Mach TSUENDA mold optical filter 61 with a ring resonator.

[0024] The inputted signal spectrum is divided into a vertical sideband using the Mach TSUENDA side optical filter 61 (K.Oda et al., IEEE J.Lightwave Technol., Vol.6, pp.1016-1023, 1988.) with a ring resonator. A photodetector 62 carries out coherent detection of the spectrum divided into the upper sideband using local oscillation light. A photodetector 63 carries out coherent detection of the spectrum divided into the lower sideband using local oscillation light. The baseband signaling detected with the photodetector 62 is compensated for distribution of an optical fiber in a delay equalizer 64. On the other hand, the baseband signaling detected with the photodetector 63 compensates distribution of an optical fiber by being inserted in a delay equalizer 65 similarly. The output of delay equalizers 64 and 65 is added with an adder 66, and is outputted through a low pass filter 67 and the distinction machine 68.

[0025] Drawing 2 shows the block diagram of the 2nd example of this invention. The same sign is given to the same component as drawing 1 among this drawing, and the explanation is omitted.

[0026] In this example, the signal spectrum component which laps with the same frequency band and which has the relative time delay of a reverse property mutually is spatially separated like the 1st example by dividing a signal spectrum into a vertical sideband using the Mach TSUENDA mold optical filter 61 with a ring resonator with a receiver 20. Coherent detection of one of the separated signal spectrums is carried out using local oscillation light with a photodetector 71. The detected baseband signaling is inputted into a delay equalizer 72, and it outputs through a low pass filter 67 and the distinction machine 68.

[0027] Drawing 3 is the block diagram of the 3rd example of this invention. The same sign is given to the same component as drawing 1 among this drawing, and the

explanation is omitted.

[0028] In this example, a transmitter 10 separates into a signal spectrum vertical sideband using the Mach TSUENDA mold optical filter 14 with a ring resonator. It transmits to a receiver 20 by making either into a sending signal among the separated signal spectrums. In a receiving side 20, the local oscillation light and receiving light from the semiconductor laser light source 21 are combined by the coupler 22, and coherent detection is carried out with a photodetector 71. Subsequent processings are the same as that of the 1st example and the 2nd example.

[0029] Drawing 4 is the block diagram of a Mach TSUENDA mold optical filter with a ring resonator. The transfer function from an output terminal 2 and an input terminal 1 to [from the input terminal 1 of the optical filter shown in this drawing] an output terminal 3 can be expressed as follows.

[Equation 1]

$$E_2 / E_1 = \frac{1}{2} \{ e^{-j(\phi + \beta m_a)} - e^{-j\beta m_b} \}$$

$$E_3 / E_1 = j \frac{1}{2} \{ e^{-j(\phi + \beta m_a)} - e^{-j\beta m_b} \}$$

Here, it is E1. The input photoelectrical community to the terminal 1 of an optical filter, and E2 The output photoelectrical community from the terminal 2 of an optical filter, and E3 The output photoelectrical community from the terminal 3 of an optical filter and beta are a propagation constant, m a, and m b. The die length of two waveguides of a Mach TSUENDA interference system and phi express the phase lag by the ring resonator 4, and are called for by the following formulas.

[Equation 2]

$$\phi = \tan^{-1} \frac{(1 - p^2)\sin\theta}{2p - (1 + p^2)\cos\theta}$$

p2 =1-k2 [however,] theta=beta m 0 -- here -- k -- the amplitude coupling coefficient of a ring resonator 4, and m 0 The ring length of a ring resonator is expressed. As mentioned above, power permeability is calculated as follows.

[Equation 3]

$$| E_2 / E_1 |^2 = \frac{1}{2} \{ 1 - \cos(\phi - \beta \Delta m) \}$$

$$| E_3 / E_1 |^2 = \frac{1}{2} \{ 1 + \cos(\phi - \beta \Delta m) \}$$

however, deltam = mb - ma -- this time -- delta m and m0 Filling the following relation is determined.

[Equation 4]

$$\beta \Delta m = \frac{\beta m_0}{2} \pm \frac{\pi}{2}$$

[0030] This is conditions which FSR of a Mach TSUEDDA mold optical filter with a ring resonator consists twice FSR of a ring resonator of. ** pi/2 is used in order to make the property of a filter steep, and to double the resonance frequency of a ring resonator with the midpoint of the core of the transparency frequency band of a Mach TSUENDA mold optical filter with a ring resonator, and the core of a cut-off frequency band. The below-mentioned computer simulation shows the frequency characteristics of this actual optical filter.

[0031] Drawing 5 shows the signal spectrum and relative time delay in this invention. This drawing shows signal SU ** KUTORU and its relative time delay at the time of performing reception by the configuration of drawing 1 . This drawing (a) is in the condition before spectrum separation. As shown in this drawing, the received signal spectrum has a relative time delay as shown by the dotted line by distribution of an optical fiber. After being multiplexed with partial oscillation light, this signal is divided into a vertical sideband as a Mach TSUENDA mold optical filter with a ring resonator shows to drawing 5 (b-1) and drawing 5 (b-2). Homodyne detection of the separated signal is carried out, respectively, and baseband signaling as shown in drawing 5 (c-1) and drawing 5 (c-2) is acquired.

[0032] In a perimeter wave number field as shows these signals to drawing 5 (d) by equalizing with the baseband equalizer which has the relative time delay of a reverse property mutually, respectively, and adding, a relative time delay can obtain a fixed baseband signaling spectrum. Since distribution is a relative time delay difference, the waveform distortion by distribution is compensated. After [all] being changed into a pace band from an optical frequency band by the above, it turns out that delay equalization is performed and it can get over by baseband processing.

[0033] Moreover, since the spectrum divided into the vertical sideband can restore also to either, the configuration of drawing 2 and drawing 3 is considered the same way. The configuration of drawing 2 detects and restores only to one of the spectrums divided into the vertical sideband by the receiving side, and the configuration of drawing 3 is a transmitting side, and transmits, detects and restores only to one of the spectrums divided into the vertical sideband.

[0034] The simulation of this invention is described below. Drawing 6 is drawing for explaining eye pattern degradation by the wavelength dispersion in computer simulation. This drawing performs eye pattern simulation by the configuration of the 1st example of drawing 1 in order to check the effectiveness of this invention.

[0035] The signal used assumed seven steps of pseudo-random signals, and made them the BPSK (Binary Phase-Shift Keying) signal of 10 Gbit/s. This drawing shows eye pattern degradation when setting wavelength dispersion of the optical-fiber-transmission way 30 to 16 ps(es)/km/nm (equivalent to the wavelength dispersion when using a 1.3-micrometer band 0 distribution fiber with 1.55-micrometer band).

[0036] In this drawing (C), although the eye pattern before transmission has not deteriorated, it turns out that an eye pattern deteriorates as a signal transmits the optical-fiber-transmission way 30 of 100km (A), 200km (D), and 300km (B).

[0037] Drawing 7 shows the power permeability property of the signal spectrum in

computer simulation, and Mach TSUENDA type light FAIRUTA with a ring resonator. In this drawing, an axis of abscissa shows a relative frequency, the scale of an axis of ordinate is linearity and two Rhine shows the power permeability property to the output 1 and output 2 in drawing 4 , respectively.

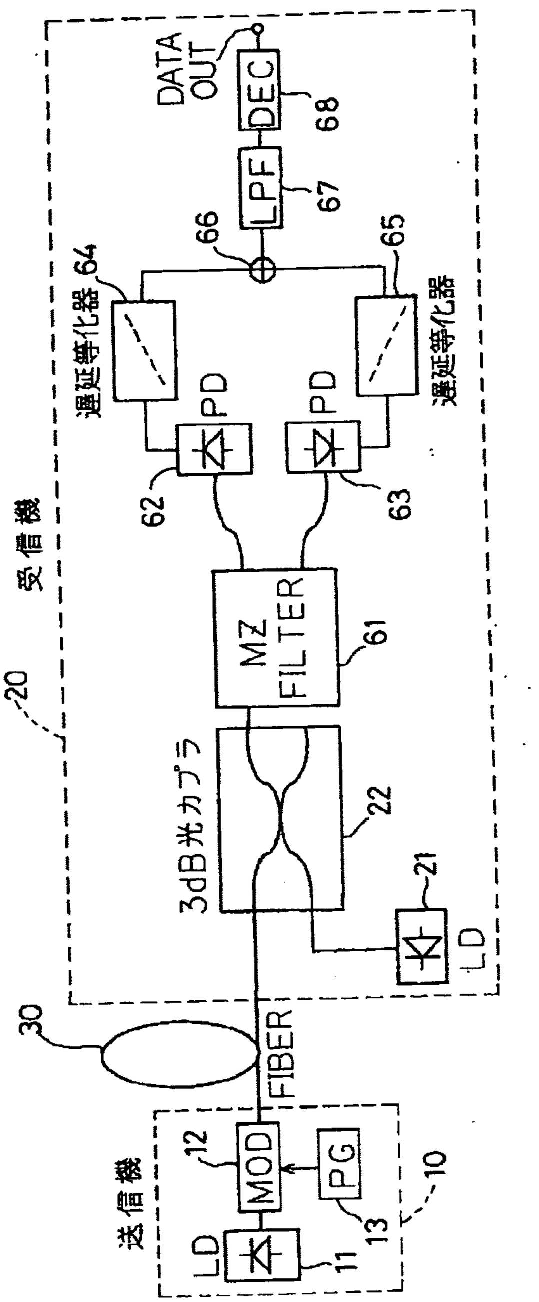
[0038] FSR of a Mach TSUENDA mold optical filter with a ring resonator is 20GHz, and the amplitude coupling coefficient of a ring resonator was set to about 0.92. Thus, after dividing into a vertical sideband the signal spectrum inputted from the terminal 1, the eye pattern as a result of carrying out a synchronous detection and an ideal baseband equalizer with which distribution of an optical fiber is compensated completely performing distributed compensation, as shown in drawing 8 with photodetectors 62 and 63 was obtained. This drawing (C) shows a signal-transmission front, and (A) is an eye pattern when 100km and (B) transmit 300km and (D) makes each 200km optical-fiber-transmission way transmit. According to drawing 8 , the eye is nearly completely open also after 300km transmission, and this invention is considered to be effective about wavelength dispersion compensation in the electric field in baseband detection.

[0039]

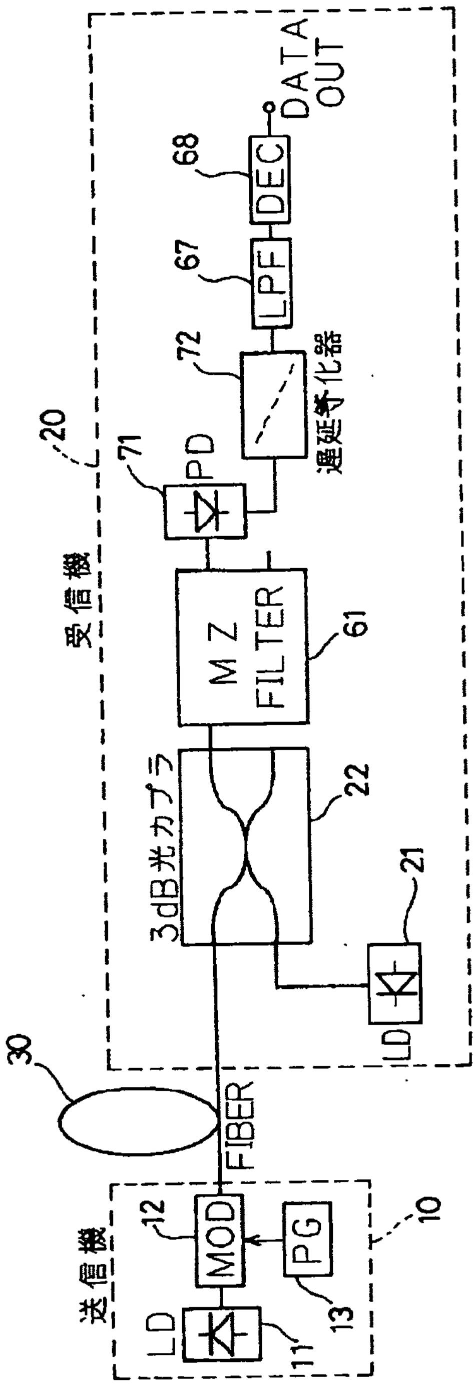
[Effect of the Invention] Distribution of an optical fiber can be compensated only with baseband processing, without carrying out a rise convert after baseband detection as mentioned above by separating the signal component which laps with baseband and which has the relative time delay of a reverse property mutually in an optical field in baseband detection of optical homodyne detection etc. according to this invention.

[Translation done.]

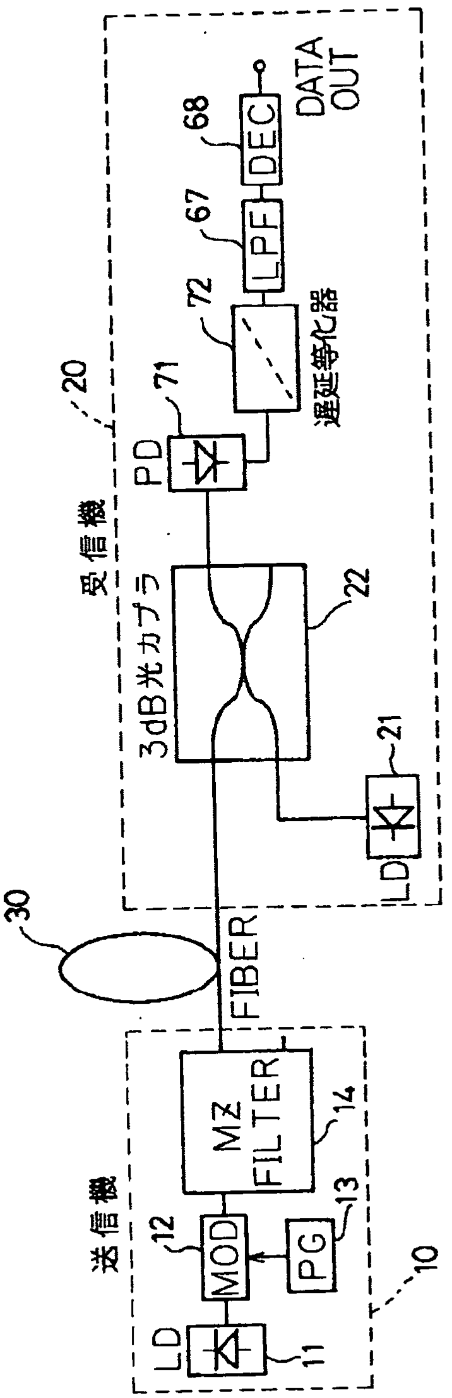
本発明の第1の実施例の構成図



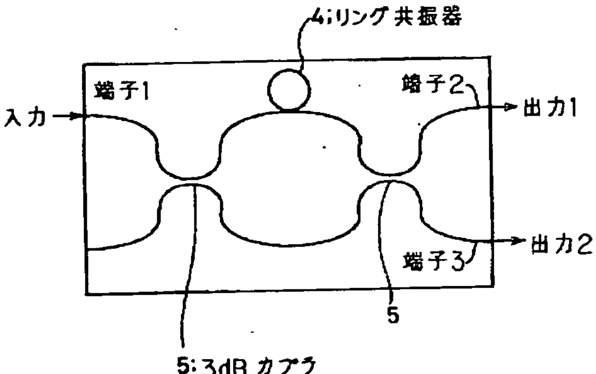
本発明の第2の実施例の構成図



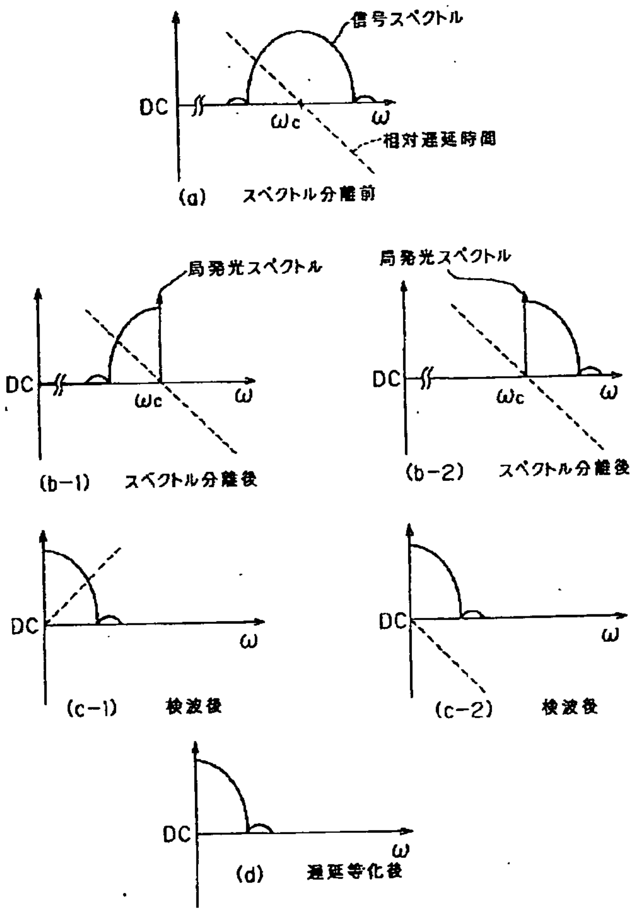
本発明の第3の実施例の構成図



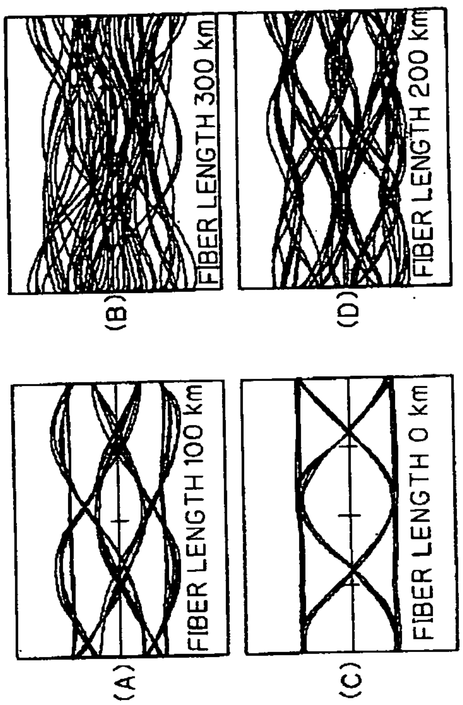
リング共振器付きマッハ・ツェンダ型
光フィルタの構成図



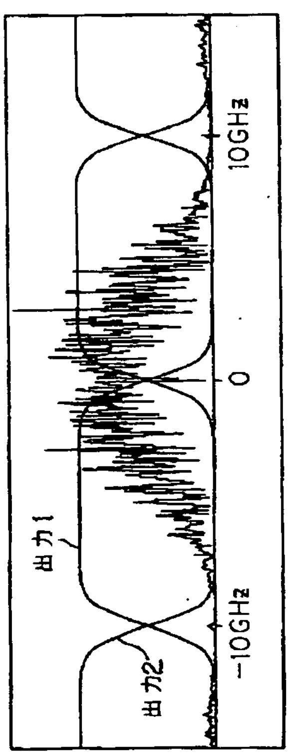
本発明における信号スペクトルと相対遅延時間



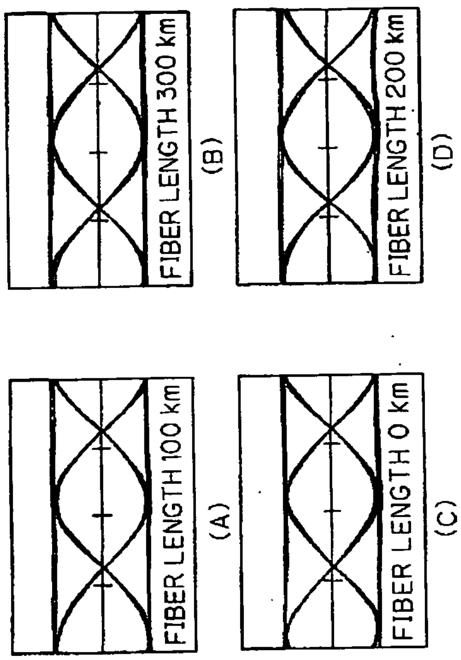
計算機シミュレーショでの波長分散による
アイパタン劣化を説明するための図



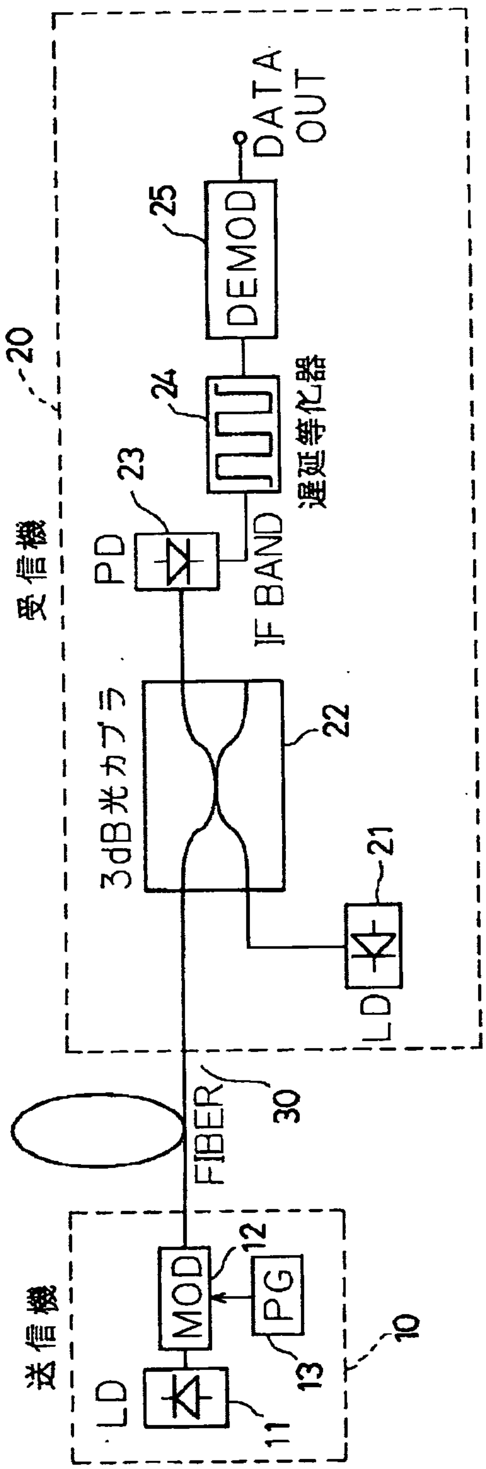
計算機シミュレーションでの信号スペクトルと
リング共振器付きマッハ.ツェンダ型光フィルタ
のパワー透過率特性を説明するための図



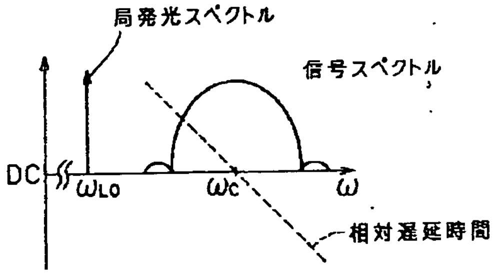
計算機シミュレーションでの理想的なベースバンド
等化器による等比後のアイパタンを示す図



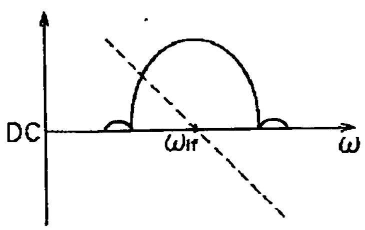
従来のヘテロダイン検波方式のブロック図



ヘテロダイン検波前後における信号スペクトルと
相対遅延時間

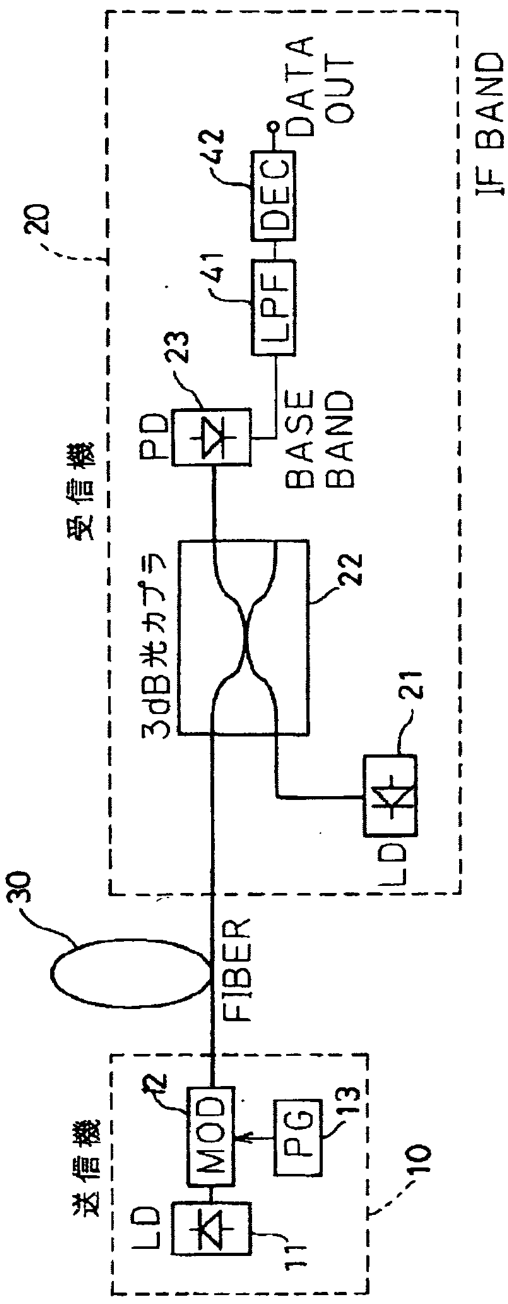


(a) 検波前（光周波数帯）

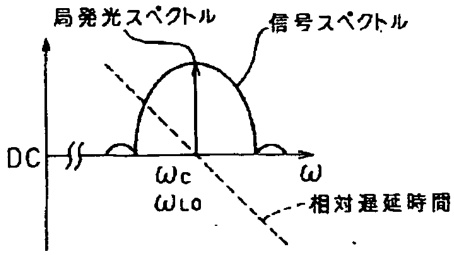


(b) 検波後（中間周波数帯）

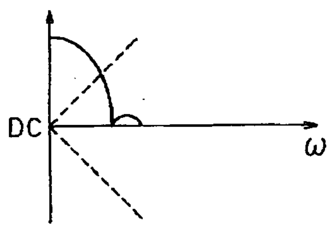
従来のホモダイン検波方式のブロック図



ホモダイン検波前後における信号スペクトルと
相対遅延時間



(a)　検波前(光周波数帯)



(b)　検波後(ベースバンド)

二重位相ダイバシティ方式のブロック図